Beam Position Monitor Data Acquisition for the Advanced Photon Source*

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Abstract

This paper describes the Beam Position Monitor (BPM) data acquisition scheme for the Advanced Photon Source (APS) storage ring. The storage ring contains 360 beam position monitors distributed around its 1104-meter circumference. The beam position monitor data acquisition system is capable of making turn-by-turn measurements of all BPMs simultaneously. It is VXI-based with each VXI crate containing the electronics for 9 BPMs. The VXI Local Bus is used to provide sustained data transfer rates of up to 13 mega-transfers per second to a scanner module. The system provides single-bunch tracking, bunch-to-bunch measurements, fast digital-averaged positions, beam position history buffering, and synchronized multi-turn measurements. Data is accessible to the control system VME crates via an MXI bus. Dedicated high-speed ports are provided to supply position data to beam orbit feedback systems.

I. INTRODUCTION

The BPM data acquisition system requirements are:

1. Measure beam position both during injection at 2 Hz and during closed orbit.
2. Provide single bunch tracking around the ring.
3. Measure position of different bunches at each BPM turn-to-turn.
4. Measure position at each BPM on each turn (3.6 microseconds for the storage ring).
5. Provide averaged beam position for higher accuracy.
6. Provide a beam history for each BPM .

Major design goals included:

1. Minimize front panel connections by using available VXI backplane lines.
2. Design the system so that BPM data acquisition will operate autonomously upon power on with no set-up/intervention by the control system.

Figure 1 shows one of 20 storage ring control nodes. Each node contains the control and BPM electronics for two storage ring sectors. The nodes are interconnected via the controls local area network (LAN) and a high-speed fiber optic ring. The BPM electronics are contained in two VXI crates with each crate containing the BPM signal processing electronics for a sector. An MXI bus connects the controls VME crate to the BPM VXI crates and a VME orbit feedback crate. The control system can set the data acquisition mode of each BPM and read, on demand, beam intensity and averaged or raw beam position.

II. METHOD

Figure 2 is a block diagram of a BPM VXI crate. The

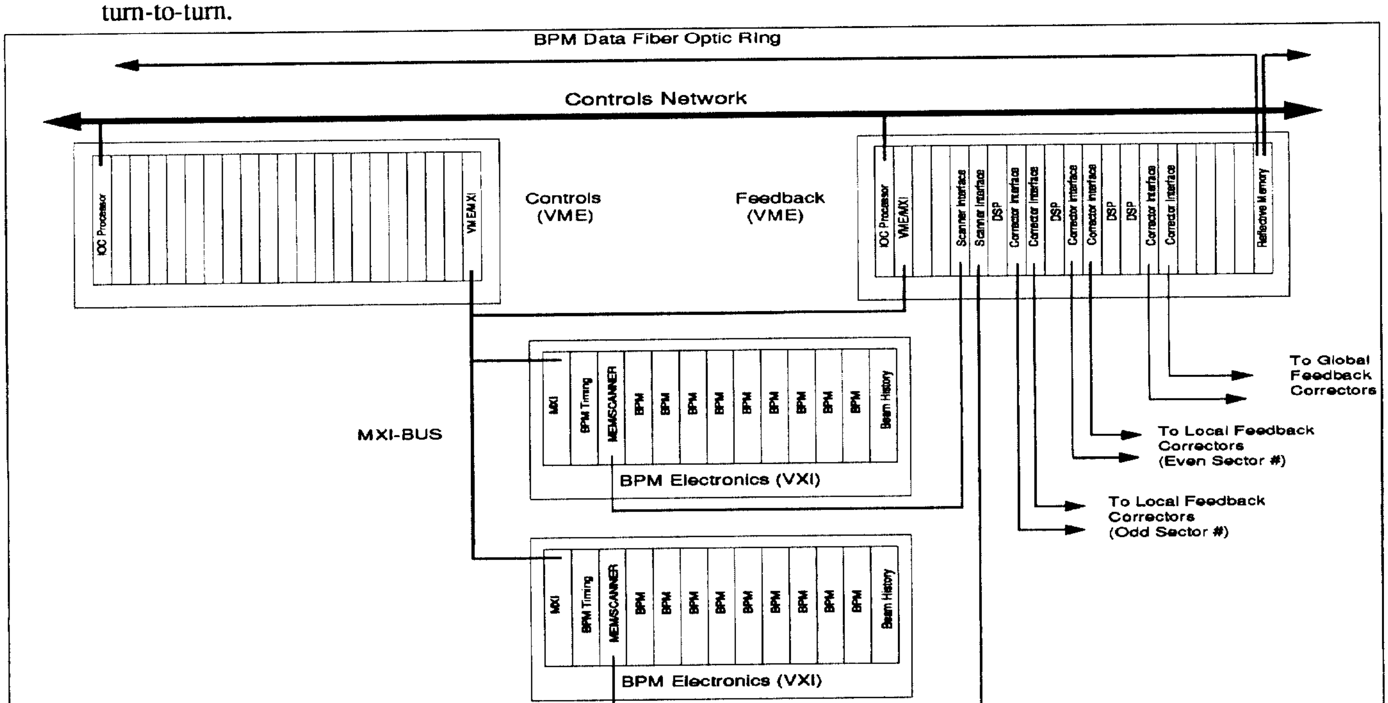

Figure 1. Typical Storage Ring Node

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VME bus lines have been omitted for clarity. The 12 VXI Local Bus lines are daisy chained through each BPM module (SCDU - Signal Conditioning and Digitizing Unit) and terminated at each end to form a 12-bit data bus. The eight VXI bus TTL Trigger lines are used for control, status, and BPM module readout select.

The Memory/Scanner module sequentially selects each BPM module at a fixed scanning rate sufficient to ensure that each BPM module will be scanned at least once per turn. For the storage ring, a scanning rate of 13 Mtransfers per second will access each BPM three times per turn. If an addressed module has new data available, it sequentially places the beam intensity followed by the position on the Local Bus lines and asserts a New Data signal to indicate the presence of data. The BPM module also drives an additional time multiplexed signal to indicate a summary module status and whether the X or Y position is currently being transferred. The BPM module is capable of digitizing only the X or the Y position on any given turn. The control system may set each BPM to measure X or Y only or alternate between X and Y on successive turns. The Memory/Scanner accepts the data on the Local Bus lines when New Data is signalled by a BPM module.

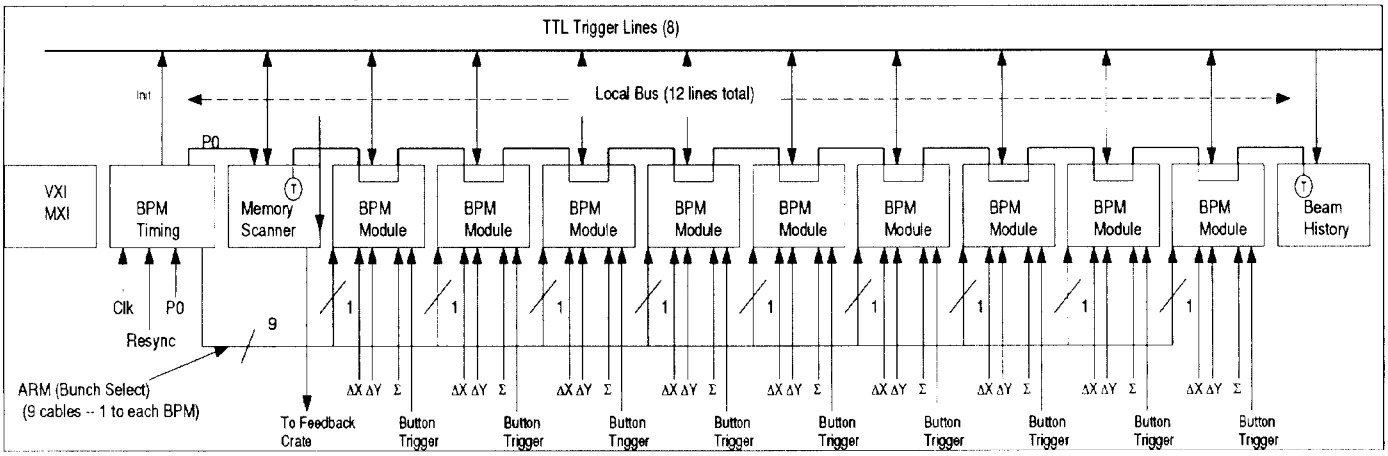

Figure 2. BPM Data Acquisition Block Diagram

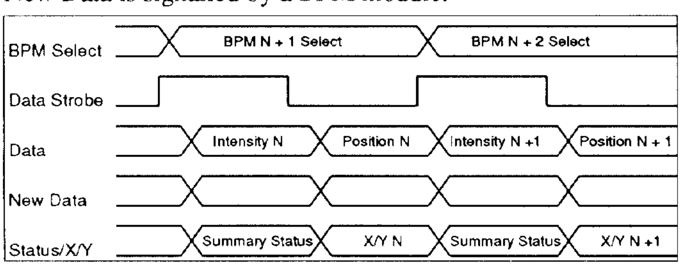

Figure 3. Data Transfer Over the Local Bus

Figure 3 shows the data transfer cycle over the VXI Local Bus. Transfers are synchronous, with timing controlled by a Data Strobe signal driven by the Memory/Scanner. A 4-bit BPM module readout address is output by the Memory/Scanner module on the positive edge of the Data Strobe. If the addressed module has new data, it responds by driving the Data lines, New Data, and the Status/X/Y lines. If New Data is asserted, the Memory/Scanner module accepts intensity data on the falling edge of Data Strobe and position (either X or Y as indicated by the Status/X/Y line) on the rising edge. The Summary Status is the OR of BPM module error status bits. The BPM Select, Data Strobe, New Data, and Status/X/Y signals are located on the VXI TTL Trigger lines. Our measurements indicate that greater than 13 Mtransfers per second are achievable using backplane transceiver logic (BTL) drivers and receivers.

Each module in the BPM system is designed to default to a running condition on power up; i.e. on power up data collection begins after a short initialization phase without intervention by the control system. The control system can alter the default power on operation through the MXI/VXI bus.

III. MODULE DESCRIPTIONS

BPM Module

Each BPM module [1] provides the signal conditioning and analog-to-digital conversion for a 4-button BPM. An onboard mono-pulse receiver accepts sum and difference signals from a front-end filter comparator located at the button pickups and outputs beam intensity and normalized position. Two channels of 12-bit digitization are provided. One channel digitizes intensity while the second channel digitizes position. The position channel may be programmed to digitize X only, Y only, or alternate X and Y on successive turns. A digitization cycle takes approximately 900 ns.

Each BPM module accepts a Bunch Select (ARM) signal and a button trigger signal. The Bunch Select signal is generated by the BPM timing module and acts as a gate for the button trigger signal, which is a fast trigger derived from the button pickups. The trigger circuitry will run in a "free run" mode if the ARM signal is disconnected or held active. In this mode the BPM module triggers on the "next" button trigger signal after completing a digitization cycle. This mode will be used during injection.

In addition, a signal derived from the button trigger signal is available on the front panel for use with other equipment.

Memory/Scanner

The Memory/Scanner controls the BPM data acquisition by driving BPM module select lines and the Data Strobe. This module provides a programmable box car averager for each

BPM X and Y position. In addition, a high speed fiber optic port provides a BPM position data stream to the orbit feedback crate.

At power up, the Memory/Scanner module sequentially initializes the readout addresses of the BPM modules and begins sequential scanning.

BPM Timing

The BPM timing module generates a bunch select (ARM) signal for each of the BPM modules. The bunch select signals are generated by arbitrary bit-pattern generators running at 117 MHz. This provides a time resolution of 8.5 ns. Each bit-pattern generator has a 4-kbyte memory which is loaded by the control system to select a bunch pattern.

The timing module also provides a "Bunch 0" reference (P0) and a "Resync" signal which is used to selectively synchronize BPM modules.

At power on the timing module forces all bunch select signals active. This causes each BPM to run in "free run" mode.

Beam History

The Beam History module provides storage memories for each BPM. It captures data transfers on the Local Bus and stores time-stamped intensity and position information. The time stamp is based on a turns counter driven by the bunch 0 reference from the BPM timing module. The 32k by 32-bit memories operate as first-in first-out (FIFO) buffers and are capable of storing ~50 milliseconds of storage ring BPM data.

Each FIFO may be operated in fill and stop mode or circular mode. The fill and stop mode will be used to collect data during machine experiments. In this mode the FIFO for each participating BPM is initially cleared. Data collection begins upon receipt of the Resync signal from the BPM timing module and ceases upon FIFO full.

In the circular mode, each FIFO fills and then overwrites the oldest data point with new data. Since the BPM modules are triggered by a beam-derived signal, digitizing ceases upon loss of beam. The FIFOs therefore will contain the beam history prior to beam loss. The circular mode will be useful in diagnosing beam loss events.

IV. ORBIT FEEDBACK SYSTEMS

As shown previously in Figure 1, each storage ring node has a VME feedback crate. The distributed feedback system architecture relies heavily on a technology known as reflective memory. Reflective memory can be defined as a network of replicated shared memory. Reflective memory has the following features:

1. Any node can write to reflective memory.
2. All nodes see the same reflective memory image (data is replicated in every reflective memory.)
3. Reflective memory is designed for real-time performance -- latency is minimized.
4. No processor involvement is required for network initialization or operation.
5. Data is transferred (replicated) by merely writing to memory -- actual transfer is handled by hardware.

Reflective memories are connected in a fiber optic ring. With presently available commercial hardware, sustained data transfer rates of 6.2 to 26 Mbytes per second are achievable. A network may consist of up to 256 nodes. At 26 Mbytes/sec up to 300m spacing between adjacent node is allowed.

The 20 orbit feedback crates distributed around the 1104-meter storage ring circumference are networked with reflective memories. Each crate receives local BPM data from the Memory/Scanners. The BPM position data is averaged by a programmable boxcar averager located in the feedback crate. Forty X and forty Y BPMs will be selected to provide global position information. An additional two X and two Y BPMs will be used for each installed insertion device beamline and an additional two Y BPMs for each installed bending magnet beamline. The beamline position data may come from rf BPMs or X-ray BPMs or some combination of both. All BPM data used for orbit correction is written to reflective memory. For the fully populated ring with 34 insertion devices and 34 bending magnet beamlines, a total of 284 positions will be used for orbit feedback. With 26-Mbyte-per-second memories, the position data will propagate around the storage ring in less than 50 microseconds. The planned feedback system sample rate will be 4 kHz [2].

Within each feedback crate, Digital Signal Processors (DSPs) use the feedback position data to calculate corrector values for the two local sectors. The global position data is used to calculate local corrector values assigned to the global feedback system. For reasons beyond the scope of this paper and related to overall feedback stability, the corrector calculations for the local beamlines use both global position data and position data associated with the local beamline.

The use of reflective memory greatly facilitates a distributed feedback system by making all BPM data required for orbit feedback available to all distributed feedback processors. Also, since each feedback node calculates corrector values for its two sectors, the need to distribute computed corrector values around the storage ring is eliminated.

V. STATUS

At the time of this writing, a prototype BPM timing module is under test. A contract to build the BPM modules to a performance specification is in place with prototypes due in June. The Memory/Scanner module detailed design is compete and is currently in CAD. Design of the Beam History module is underway. Proof of concept tests for the feedback systems are scheduled to take place at SSRL.

VI. REFERENCES

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